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OUTLINE

- Constructability
- Demands on a concrete mixture
  - Relating construction practices to concrete properties
  - Example
- Workability and constructability
- Monitoring and controlling workability
- Conclusions

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Definition

Constructability—The effective and timely integration of concrete construction knowledge into the conceptual planning, design, construction, and field operations of a project to achieve the overall project objectives in the best possible time, with the highest safety, and at the most cost-effective level of quality.

"Defining Concrete Constructability; A proposal for consideration and action" by Larry G. Karlson, Eamonn F. Connolly, Christopher M. Garcia, and Bruce A. Suprenant – Concrete International, October, 2018

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The Concrete Mixture

- The performance targets of concrete mixtures depend on who you are talking to.

Cumulative

Owner	How long will my structure last? When can I open it?
Architect	How does it look? Is the functionality present?
Engineer	Is it strong enough? Durable enough?
Contractor	Can I place it? Can I finish it?
Concrete Producer	Can I make it economically and efficiently?

- **Critical Concept**

Performance Desires → **Concrete Properties** → **Mixture Proportions**

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Construction Practices and Concrete Properties

	Placing	Consolidating	Screeding	Floating	Edging	Final Finishability	Form Removal	Continuing Construction

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Project Example – Power Plant

Use	Class	Exposure	Minimum 28 Day Strength, psi (Mpa)
Cooling Tower - All - Foundations/footings, slabs, walls, risers, columns, upper and lower shell	I-B	F2, S2, P1, C2	5000 (35)

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Slump

- Concrete slump – As low as possible without sacrificing workability
- 3.10.13 Consolidate placed concrete with mechanical vibrating equipment according to ACI 301-05.
- 3.10.14 Do not use vibrators to transport concrete inside forms. Insert and withdraw vibrators vertically at uniformly spaced locations to rapidly penetrate placed layer and at least 6 inches into preceding layer. Do not insert vibrators into lower layers of concrete that have begun to lose plasticity. At each insertion, limit duration of vibration to time necessary to consolidate concrete and complete embedment of reinforcement and other embedded items without causing mixture constituents to segregate.

How Long? How do you know?

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Slump Impact on Consolidation

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Viscosity

	Exposure	Condition	Mixture proportioning Impact
F0-F3	F2	Concrete exposed to freezing and thawing cycles with frequent exposure to water	1) Air entrainment - spec called for 6% +/- 1.5%. 2) Max w/cm = 0.45
S0-S3	S2	Water soluble sulfate in soil (% by mass) 0.20<SO42-<2.00	1) Max w/cm ratio = 0.45. 2) Limitations on cement type. 3) Possible use of other SCMs or blended cements.
		Dissolved sulfate in water (ppm) 1500<SO42-<10000	1) Max w/cm ratio = 0.45
P0-P1	P1	Concrete required to have low permeability to water	1) Max w/cm = 0.50
C0-C2	C2	Concrete exposed to moisture and an external source of chlorides from deicing chemicals, salt, brackish water, seawater, or spray from these sources	1) Max w/cm ratio = 0.40. 2) Max water-soluble chloride ion content in concrete (% by wt of cement) = 0.15. 3) Possible use of silica fume. 4) Possible use of other SCM's. 5) Possible use of Calcium Nitrite CI.

Air = 6% +/- 1.5%
w/cm = 0.40
Cement Type
SCM's
CI Admixture

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Viscosity

Air = 6% +/- 1.5%
w/cm = 0.40
Cement Type
SCM's
CI Admixture

↓

30-year
service life
w/cm = 0.35

Minimum cementitious content	650 lb/yd3 (385 kg/m3)
Maximum w/cm ratio	0.45
Ratio of fine to total aggregates	0.50

	lb/yd3	kg/m3
Cement Factor	650	385
Coarse Aggregate	1600	940
Fine Aggregate	1500	890
Water	230	135
Air Content	6%	6%

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Evaluation

	1	2	3	4
Cement content	650 (385)	650 (385)	700 (415)	700 (415)
w/cm ratio	0.35	0.40	0.35	0.40
Water content	228 (135)	260 (154)	245 (145)	280 (166)
CNI admixture	6 (30)	6 (30)	6 (30)	6 (30)

Measurements
- Slump
- Stickiness/Viscosity
- Workability Retention

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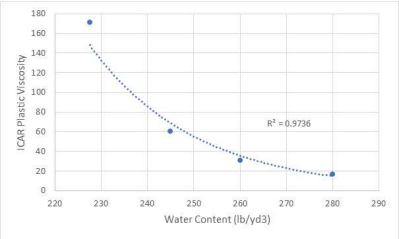
Stickiness/Viscosity



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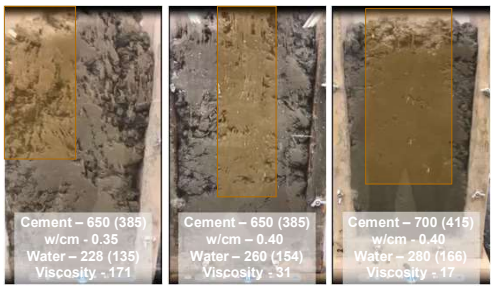

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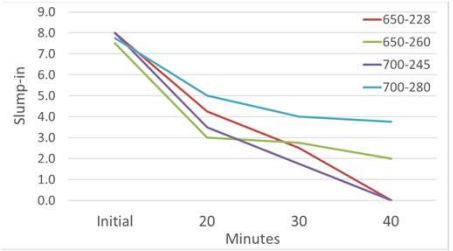
Slump Loss



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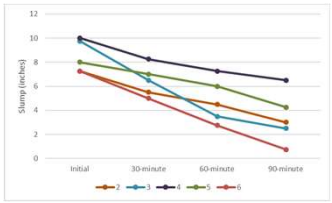
Slump Loss

- 5 locations around N. America
- Using local materials only
- Identical concrete proportions
  - CF – 705 lb/yd3 (418 kg/m3)
  - Water – 290 lb/yd3 (172 kg/m3)
  - Non AE

Region	28-Day (psi)	Re-temper water (gal/yd3)	Final w/cm	28-Day re-temper (psi)
2	8300	5.3	0.475	6800
3	7600	9.6	0.524	5315
4	6440	5.5	0.476	5530
5	7455	4.5	0.465	6670
6	6540	5.4	0.475	5780



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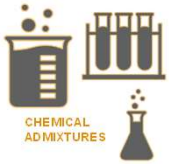
What Do We Do?

Performance/Data Transparency

Apply The Right Solution



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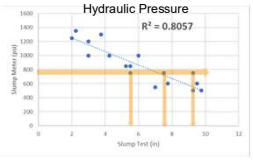
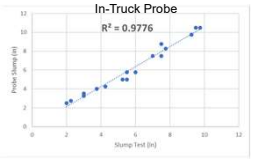
Data Availability





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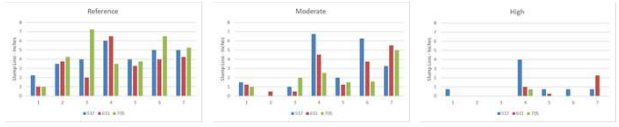
Choose the Right Solution

1. Retarding Admixtures
2. Hydration Control Admixtures
3. Workability Retaining Admixtures



90-Minute Slump Loss

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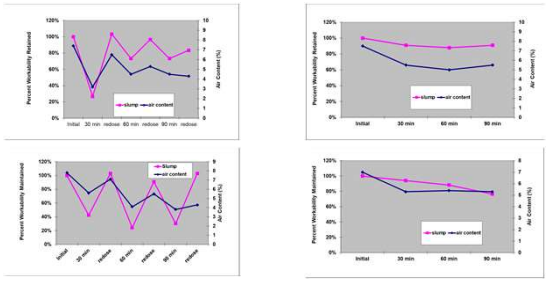
Relationship Between Slump and Air content



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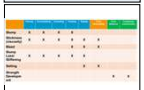
Conclusion

Interconnected Desires	Communication	Workability and Constructability	Solutions
			
• Owner • Architect • Engineer • Contractor • Producer	• Performance Desires • Concrete Properties • Mixture Proportions	• Slump • Viscosity • Slump Loss	• Data Transparency • Admixture Technology

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QUESTIONS?

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